

Airborne Hyperspectral Remote Sensing

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Award Number: N0001499WX30247

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LONG-TERM GOALS

Visible radiation is the only electromagnetic tool that directly probes the water column, and so is key to Naval systems for bathymetry, mine hunting, submarine detection, and submerged hazard detection. Hyperspectral imaging systems show great promise for meeting Naval imaging requirements in the littoral ocean. To support the development of these applications and to test design features for the Coastal Ocean Imaging Spectrometer (COIS) to be flown on the Naval Earth Map Observer (NEMO) spacecraft (Wilson and Davis, 1998, in press) in 2001 we have designed and built the Ocean PHILLS instrument. The overall goal is to demonstrate the utility of airborne and spaceborne hyperspectral imaging for the characterization of the littoral zone.

OBJECTIVES

This task was to collect data during a field campaign to Lee Stocking Island in the Bahamas to demonstrate the utility of hyperspectral systems for this shallow water environment. We imaged the entire study area on five days while other investigators collected in-water optical properties and conducted studies of the sediments, seagrass and corals. The objective is to correlate the hyperspectral imagery with the detailed in-situ measurements and to use the combined data set to develop algorithms for characterization of the coastal ocean using hyperspectral data.

APPROACH

The Ocean Portable Hyperspectral Imager for Low-Light spectroscopy (Ocean PHILLS), is a new hyperspectral imager specifically designed for imaging the coastal ocean. It uses a thinned, backside illuminated CCD for high sensitivity, and a newly designed all-reflective spectrograph with a convex grating in an Offner configuration to produce a distortion free image. It images in 128 spectral bands over the range 400 to 1000 nm. Data is collected for 1000 pixels across track, and in this experiment the pixels were 1.5 m wide and the swath covered 1.5 km.

The Ocean PHILLS instrument was used in the Office of Naval Research (ONR)-sponsored Coastal Benthic Optical Properties (CoBOP) experiment at Lee Stocking Island, Bahamas in May-June 1999. The focus of CoBOP is the interaction of light with the benthic environment – the seafloor and bottom dwelling organisms – in various environments including sediment, seagrass and coral reefs (Mazel, 1998). In addition to the basic science there is a directed effort in remote sensing for seafloor imaging and classification. The field experiments are designed to coordinate the in situ data collection needed

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 1999		2. REPORT TYPE		3. DATES COVERED 00-00-1999 to 00-00-1999	
4. TITLE AND SUBTITLE Airborne Hyperspectral Remote Sensing				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory, Code 7212, 4555 Overlook Ave, S.W., Washington, DC, 20375				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

for the basic science initiatives with that needed to provide ground truth for validating the remote sensing images.

WORK COMPLETED

Five flight lines were flown on each of five days during the CoBOP study. The lines run at an angle of 83° , which is aligned with the solar azimuth during the scheduled flight hour of 9:00 - 10:00 am local time. The time of day was selected to achieve a solar zenith angle of about $40^\circ - 55^\circ$ in order to minimize sun glint, and the direction minimizes differential lighting across the scene. The aircraft used was an Antonov AN-2 Soviet-design biplane, operated by Bosch Aerospace (www.boschaero.com). The aircraft is capable of sustained low speeds of 85-90 knots (45 m/s), ideal for maximizing signal level over dark water targets. Lines 1, 2, 3, and 5 are each about 8 km long, and were each covered in about 3 minutes. Line 4 is 12 km long, extending to the east where the water becomes very deep and suitable for deep water calibration. All five lines were generally covered during the one hour flight window.

Figure 1 shows a quick look mosaic of the data collected on one of the days. The study area includes different bottom types – coral, sand, seagrass – sometimes within the same local area, at a variety of depths. Most of the region is quite shallow; the deepest point between the two islands is only 7 m deep. East of Lee Stocking Island (bottom of the image) the depth increases more rapidly, but the coral reefs at North Perry and Horseshoe are visible through the water. The deep water calibration site, at the end of Line 4 (off the image) is in water hundreds of meters deep where the bottom is not visible. Shipboard measurements of remote sensing reflectance made at the same time as the overflight will be used to validate the aircraft measurements and atmospheric correction.

RESULTS

Data from all five flight lines were collected successfully on five days. As an example Figure 2 shows part of flight line 2 from June 1, 1999. The characteristics of the different bottom types are visible even in this single-band image from 560 nm. The dark area west of Norman's Pond Cay (inside the box) is the grapestone, which is oolitic sand grains (very fine sands of precipitated calcium carbonate) cemented together. The dark area east of the Cay is relatively deep water, and the bright white areas are shallow shoals, less than 2 m deep, with sandy bottom. There are dark patches of seagrasses near the northwest of Lee Stocking Island. East of Lee Stocking Island are the coral reefs in the area where the image becomes darker. Spectra from the Grapestone area are shown in Figure 2. These are calibrated data, but they have not been atmospherically corrected, and show the radiance at the aircraft. Although they include the path scattered radiance from the atmosphere, there are still very identifiable differences between the bright sandy area, the darker grapestone, and the shallow nearshore region.

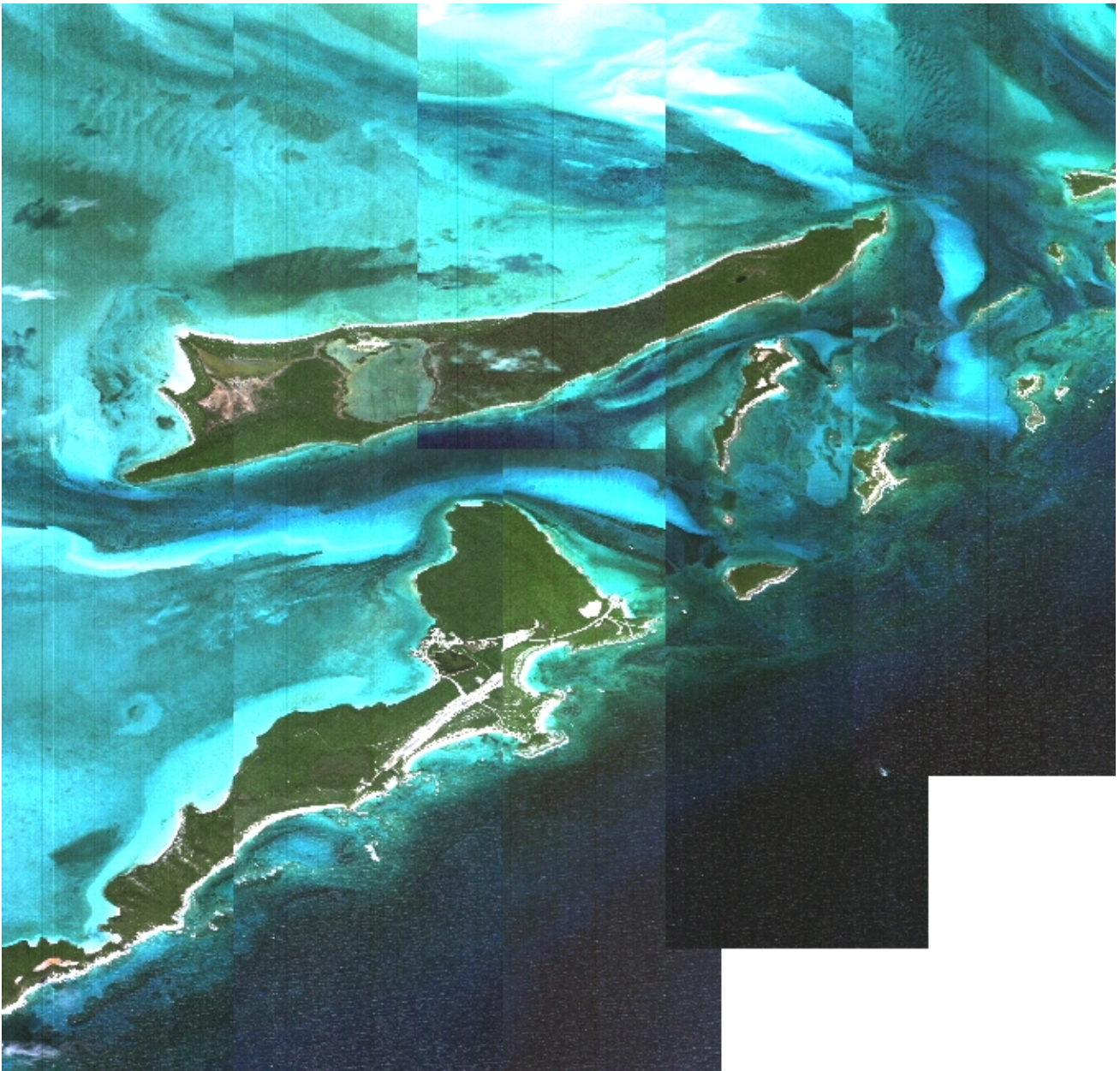


Figure 1. Quick look data from the five standard flight lines (parallel lines running roughly east to west) flown June 1, 1999 during the CoBOP experiment at Lee Stocking Island (at bottom of image), Bahamas. North is at the right of the image. Some of the flight lines are longer, but have been cropped for display.

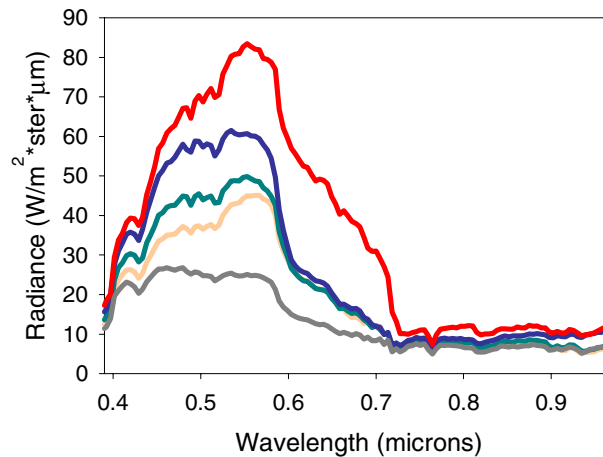
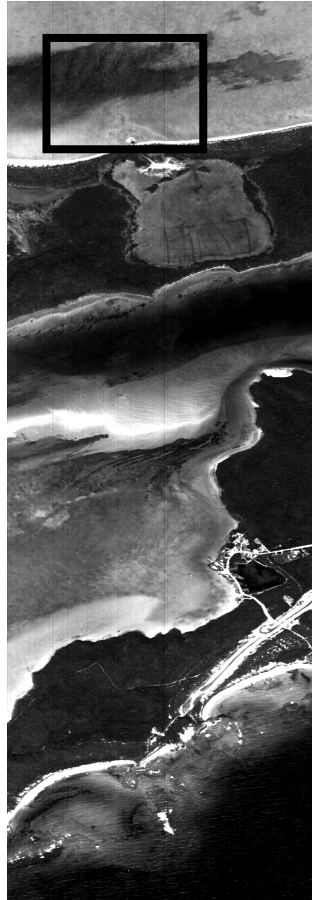


Figure 2. A single band image of flight Line 2 from June 1, 1999. West is at the top of the image and East is at the bottom. Example calibrated spectra taken from the Grapestone area (box) are shown in the graph on the right. The darkest spectra is the grapestone, and the highest signal is from a shallow sandy area.

IMPACT/APPLICATIONS

The Ocean PHILLS produces high quality spectral imagery of the coastal ocean. The data has very good sensitivity for ocean scenes as demonstrated in the CoBOP experiment. A key element in this success is the VS-15 spectrograph developed jointly by NRL and American Holographic, Inc. There is no measurable (< 0.1 pixel over the full field of view) smile or keystone in the imagery. All of the components of the Ocean PHILLS are now commercially available. This opens the possibility that a number of people will make similar instruments, making hyperspectral imaging much more widely available for a variety of applications. A key to the utilization of this data will be the product algorithms, such as those that will be developed based on the CoBOP data.

TRANSITIONS

The Ocean PHILLS data will be shared with the CoBOP participants. When combined with their in-water data we anticipate jointly developing algorithms for shallow water bathymetry and the characterization of a diversity of bottom types.

RELATED PROJECTS

This effort is closely coordinated with the Coastal Benthic Optical Properties (CoBOP) program (Mazel, 1998).

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PUBLICATIONS

- Davis, C. O., M. Kappus, J. Bowles, J. Fisher, J. Antoniadis, and M. Carney, "Calibration, Characterization and first Results with the Ocean PHILLS Hyperspectral Imager", *Proceedings of the SPIE*, V. **3753**, In Press.